(10)

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 :		(11) International Publication Number:	WO 91/16598
G01B 11/00	A1	(43) International Publication Date:	31 October 1991 (31.10.91)

(21) International Application Number: PCT/NO91/00063

(22) International Filing Date: 23 April 1991 (23.04.91)

(30) Priority data:
901831 25 April 1990 (25.04.90) NO

(71) Applicant *(for all designated States except US)*: METRONOR A/S [NO/NO]; Fekjan 13, N-1360 Nesbru (NO).

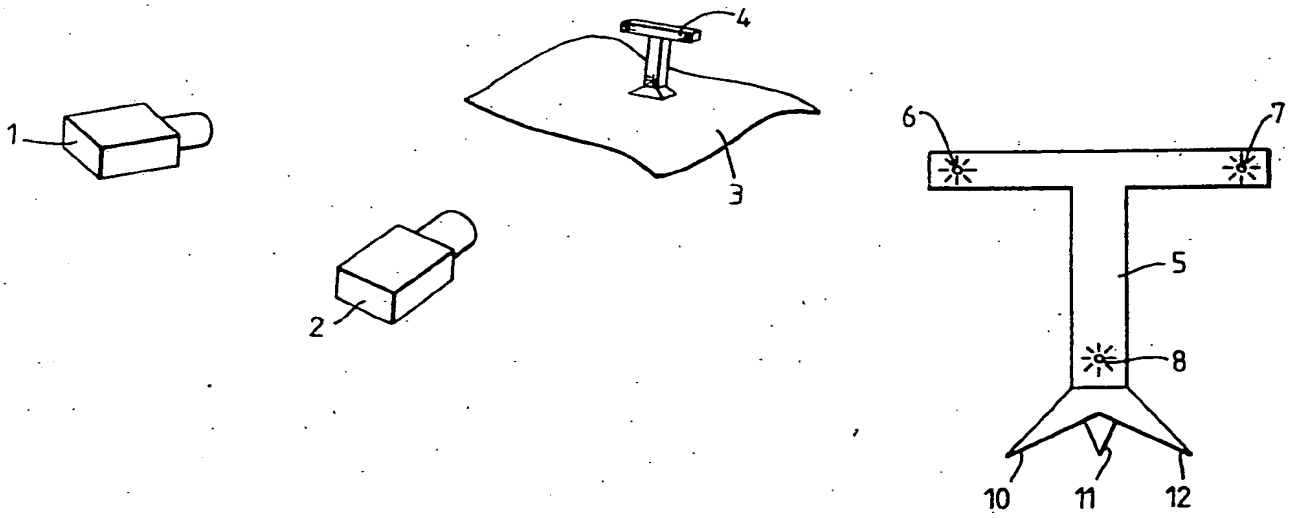
(71)(72) Applicants and Inventors: LINDQVIST, David [SE/SE]; Furuhällsvägen 5, S-435 44 Mölnlycke (SE). PETTERSEN, Alf [NO/NO]; Emil Stangs vei 27B, N-1346 Gjettum (NO). RØTVOLD, Øyvind [NO/NO]; Lidarende 1, N-1364 Hvalstad (NO).

(74) Agent: LANGFELDT, Jens, F., C.; Bryns Patentkontor A/S, P.O. Box 9566, Egertorget, N-0128 Oslo 1 (NO).

(81) Designated States: AT, AT (European patent), AU, BB, BE (European patent), BF (OAPI patent), BG, BJ (OAPI patent), BR, CA, CF (OAPI patent), CG (OAPI patent), CH, CH (European patent), CM (OAPI patent), DE, DE (European patent), DK, DK (European patent), ES, ES (European patent), FI, FR (European patent), GA (OAPI patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KP, KR, LK, LU, LU (European patent), MC, MG, ML (OAPI patent), MR (OAPI patent), MW, NL, NL (European patent), NO, PL, RO, SD, SE, SE (European patent), SN (OAPI patent), SU, TD (OAPI patent), TG (OAPI patent), US.

Published
With international search report.

(54) Title: DEVICE FOR DETERMINATION OF THE TOPOGRAPHY OF A SURFACE



(57) Abstract

The present invention relates to a device for determination of the topography of a surface by measuring its normal vector point by point, as well as devices for determination of the curvature of the surface in these points, and for determination of the orientation, position, shape and size of holes in the surface. The said devices are based on the use of opto-electronic sensors (1; 1-2) for measurement of the spatial position of active light sources. The invention is furthermore based on an accessory tool (1; 4) consisting of a body (3a; 5), a minimum of two light sources (3a; 6-8) and three contact pins (3a; 10-12) or a plane contact surface. The contact pins or the contact surface positions the tool unambiguously onto a surface (1; 3). By knowledge of the positions of the light sources relative to the contact pins or contact surface of the tool, the orientation of this surface can be determined from the measured spatial coordinates of the light sources.

19

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland			SN	Senegal
CI	Côte d'Ivoire	KR	Republic of Korea	SU	Soviet Union
CM	Cameroon	LI	Liechtenstein	TD	Chad
CS	Czechoslovakia	LK	Sri Lanka	TG	Togo
DE	Germany	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

Device for determination of the topography of a surface.

The present invention relates to a device for determinatior of the topography of a surface by measuring the normal vector of the surface point by point, as well as devices for determination of the surface curvature in the same points, and for determination of orientation, position, shape and size of holes in the surface.

The said devices are based on the use of opto-electronic sensors for measurement of spatial positions of active light sources, e.g. as described by two of the inventors (Petterser and Røtvold) in Norwegian Patent Application no. 881579. An accessory tool allowing for marking measurement points on a surface, as well as for determination of the position of points hidden from the sensors, is previously developed by one of the inventors (Lindqvist), ref. Swedish Patent Publication no. 456454. The present invention relates to a further development of this accessory tool, as this now allows for point by point determination of the normal vector of the surface and possibly its curvature at these points, as well as position, shape, size and orientation of holes in the surface.

There is in industry a strong need to map the topography of surfaces. As an example this regards to automotive industry where there is a need for quality control of manufactured curved surfaces, and for digitization of model surfaces during the design process.

In relation to the use of Computer Aided Design systems the normal vector of the surface is very often used to the describe its shape. This gives valuable information in addition to coordinates of points on the surface. All known methods for surveying objects are based on measurements o:

coordinates of individual points. There are no known methods for direct, physical measurement of the normal vector point by point across a surface.

The present measurement techniques are to a large extent based on mechanical coordinate measurement machines, which only allow for determination of spatial coordinates of points on the surface. The normal vector has in such case to be derived from the coordinates of neighboring points. The same limitations are valid for all known systems based on non contact measurements e.g. by the use of video cameras and laser scanning, or conventional photogrammetry based on making photographs of marked points on an object or a surface.

It is an object of the present invention to supplement the coordinate values measured point by point by information on the surface normal vector and eventually its curvature in the same point. A measurement point can be freely chosen anywhere on the surface, or it can be defined by the edge of the surface. Furthermore it is an objective to completely describe holes in the surface or the object, by determination of the position, diameter and orientation of the holes.

The device is based on the use of movable sensors. This allows for surveying large objects without needing to transport them to a measurement laboratory. The said accessory tools can as well be used to determine the relation between the coordinate systems in question, i.e. the inner coordinate systems of the sensors, and the coordinate system of the object. Determination of these relations are based on photogrammetrical principles.

According to the present invention this is obtained by a probe comprising a body, a minimum of two light sources and three contact points or a plane contact surface, where the positions of said light sources are known relative to the

contact points or the contact surface, in such a way that when measuring the spatial position (coordinates) of these light sources using said sensors, this gives the basis for calculating the coordinates of said contact points as well as the normal vector to the plane defined by the contact points or the contact surface.

According to the present invention probes are suggested that comprise two or three light sources. Furthermore various ways of designing the contact points or contact surface of the probe are suggested, and hence additionally to be able to determine the curvature of the surface, or the normal vector on the surface in points defined by the edge of the surface. Furthermore a special design of the probe is suggested to allow for determination of the position, orientation, shape and size of holes in the surface.

Further characteristic features are given in the subsequent patent claims, as well as in the following description of examples being non-limitative to the invention, with references to the accompanying drawings.

Figure 1 illustrates a measurement scenario where two sensors and an accessory tool are used to determine the surface normal.

Figure 2 a-b illustrate the basic construction of the accessory tool, based on a plane contact surface.

Figure 3 a-b illustrate an accessory tool based on three contact pins.

Figure 4 a-b illustrate an accessory tool which in addition to the surface normal also give a direct measure of the curvature of the surface in the measurement point.

Figure 5 illustrates a tool which gives the surface normal in a point defined by a hole in the surface, in addition a measure of the position and diameter of the hole.

Figure 6 illustrates a tool for determination of the direction, position and diameter of a hole.

Figure 7 a-c illustrate tools for determination of the normal vector at the edge of a surface.

The use of a measurement device according to the present invention comprises positioning of two sensors 1, 2 for determination of positions of light sources or light spots located on a surface 3. The sensors may be of the kind described in Norwegian Patent Application 881579, or other light sensitive detectors. An accessory tool 4 is located in required position on the surface. The basic construction of the tool is shown in figures 2 a-b and 3 a-b. It consists of a body 5 with light sources 6-8 and a plane contact surface 9 (fig. 2) or three contact pins 10-12 (fig. 3). A probe having three light sources can for example have a T-shaped body (fig. 2 a, 3 a-b), having one light source mounted in each end of the lateral bar and one at the foot of the vertical pole. The use of three light sources is and advantage, as this give an unambiguous definition of the normal vector.

The measurement principle is that the two (or more) sensors register the position of the individual light source. Based on the information on the position of the light sources on the tool, the position and orientation of the tool as a hole are calculated. As an example, photogrammetrical computational methods can be used for these calculations principles.

The minimum number of light sources is two, as shown in figure 2 b. This requires the two light sources 7-8 to be

mounted on line parallel to or coinciding with the normal vector. If the positions of the light sources are known relative to the point where the line through the two light sources intersects the plane defined by the contact surface or the three contact points, this give the basis for a calculation of the spatial coordinates of this point, in addition to the normal vector.

Using three or more light sources 6-8, these are allowed to be arbitrarily mounted relative to the contact points 10-12, given that the light sources are not located in a straight line. The position of the light sources have to be known relative to a local, tool fixed coordinate system. This local coordinate system will be defined by the position and orientation of the contact pins 10-12 or the contact surface 9. If the positions of the individual light sources are measured relative to a global or object fixed coordinate system, the position and orientation of the tool is calculated by a simple coordinate transformation.

The body 5 of the accessory tool does not need to be mounted normal to the contact surface 9 or the surface defined by the three contact pins 10-12. On the contrary, for many applications it will be advantageous to mount the body at an angle making it easier to get access to partially hidden surfaces.

By the use of the accessory tool the normal vector of the plane defined by the contact surface 9 or the contact pins 10-12 is determined. It is important that the size and shape of the contact surface or the distance between the contact pins is adapted to the curvature of the surfaces to be measured. If the surface is strongly curved within dimensions of the same order of magnitude as the distance between the contact pins, the surface normal will be undefined, or at best an average surface normal is measured.

Figure 4 a-b illustrate tools which in addition to the surface normal also supply information on the surface curvature. In figure 4 a a fourth contact pin 13, which is free to move parallel to the normal to the surface defined by the pins 10-12, is mounted in a hole 15. A light source 14 is attached to the movable pin 13. The position of this light source 14, relative to the other light sources 6-8 gives the basis to calculate the curvature of the surface. The calculated curvature will be an average for the area limited by the three contact pins.

The same functionality would be achieved by having the pin 13 mounted fixed to the body 5 of the tool, by mounting the three contact pins 10-12 such that they can be moved parallel to the surface normal as one unit, and that the light source 14 is moved thereon.

In figure 4 b two arms 25-26 are attached to the tool body 5 by the use of rotary adapters 31-32. Light sources 27-28 are fixed to each of the arms. The surface is touched by the pins 29-30. The spring-loaded couplings 31-32 ensure that the contact pins are forced down against the surface. The position of the light sources 27-28 relative to the other light sources 6-8 give a measure of the surface curvature.

Figure 5 illustrates a variation of the tool of figure 4 a, developed to determine the surface normal in points given by a hole 17 in the surface 3. A conically shaped pin 16 is movable in the vertical direction within a hole 15. A light source 14 is attached to the pin. The position of this light source relative to the other light sources 6-8 shows how deep into the hole 17 the pin 16 penetrates. If the shape of the pin is known this is a basis to calculate the diameter of the hole in addition to the center of the hole. As explained above the same effect would be achieved by the use of a fixed pin 16, if the three pins 10-12 where mounted together along the vertical axis.

The tool for determination of hole diameter as described above is restricted to circular holes in thin surfaces. Figure 6 illustrates a tool which can be used to determine the orientation, position, diameter and shape of the hole 17. The pin is in this case shaped like a cylinder 18. This cylinder is held adjacent the edge of the hole at a minimum of three different positions. A rom 19 is mounted on the top of the cylinder 18 such that the depth within the hole 17 is well defined.

The longitudinal axis of the cylinder 18 intersects the plane defined by the rim 19 in a well defined point. The positions of the light sources 6-8 are known relative to this point. In the case of circular holes 17 drilled normally into the surface 3, three measurement positions are sufficient to determine the position (center), orientation and diameter of the hole. The measurements give the spatial coordinates of three points on a circle having its center in the center of the hole, and having a diameter equal to the diameter of the hole minus the diameter of the cylinder. This is valid even if the orientation of the hole is not normal to the surface, such that the intersection between the hole and the surface is an ellipse. If, on the other hand, the hole has an ellipse shape, a minimum of four measurement points are needed.

The suggested cylindrically shaped accessory tool for hole determination can be replaced by a tool having another shape, e.g. having a well defined edge touching the side of the hole. The essential features are that the tool has a well defined contact surface or line such that the tool is naturally positioned parallel to the center axis of the hole, and that the contact surface or line is known and well defined relative to the positions of the light sources.

There is often a special need for the surface normal at the edge of a surface 3, or along feature lines or cuts in the surface. In figure 7 a it is shown how the three contact pins 20-22 can be designed to determine the surface normal in a well defined distance from the edge of the surface. In figures 7 b-c the three contact pins are replaced by one contact surface 23. This surface is mounted to the body 5 of the accessory tool by the use of a rotary coupling 24. This enables the use of the same tool around the outer edge of the complete surface, as the body and light sources of the tool always can be directed towards the sensors of the measurement system.

An example of the need for a determination of the surface normal at the edge of a surface, is in relation to the requirements in the automotive industry with respect to flush between the car body parts. This implies that for instance the edges of the mounted hood and fenders should be in flush. The same is valid for example for the transition between the fender and the door. By the use of a tool as shown in figure 7, measures both of the surface normals of the two surfaces are achieved, as well as their relative level through the coordinates of the respective contact points being known. Conventional coordinate measurement machines have proved to be useless for this application, as the use of such instruments would require a large number of measurement points, and fitting to mathematical surfaces there-through.

In the above a number of tools are suggested. All are built up from the same body 5 and light sources 6-8. A practical universal tool will be designed such that this part can be applied together with a number of differently shaped, replaceable contact surfaces and pins.

Patent claims:

1.

A device for determination of the topography of a surface by measuring the normal vector of the surface point by point, comprising a minimum of two sensors which determine the spatial position of light spots, characterized in:

- a probe comprising a body (5), a minimum of two light sources (6-8) and three contact points (10-12) or a plane contact surface (9), and where the position of said light sources are known relative to the contact points or the contact surface, such that by measuring the spatial position (coordinates) of these light sources by the use of said sensors, there is made up a basis for a calculation of the coordinates for said contact points, as well as the normal vector of the plane defined by the contact points or the contact surface.

2.

A device as claimed in claim 1, characterized in:

- two light sources (7-8) being attached to the probe, both mounted such that a line through said two light sources is parallel to the normal vector of the plane described by said contact points (10-12) or plane contact surface (9).

3.

A device as claimed in claim 1, characterized in:

- three light sources (10-12) being attached to the probe, mounted in arbitrary positions, however such that all three light sources are not located along a straight line, and that the positions of the light sources are known relative to said contact points (10-12) or plane contact surface (9).

4.

A device as claimed in claim 1, characterized in:

- a fourth contact point (13) being mounted to the probe in addition to the three contact points (10-12) and in the center of these, that this fourth contact point is movable in a direction normal to the plane described by said three fixed contact points, and that a light source (14) is attached to this fourth contact point such that by determining the position of this light source relative to the other light sources the curvature of the surface can be calculated.

5.

A device as claimed in claim 1, characterized in:

- that the contact surface (23), or one or two of the three contact points (20-22) is designed such that the probe can be located in a well defined position relative to the edge of the surface, to determine the surface normal in thereat.

6.

A device as claimed in claim 1, characterized in:

- that a guiding means (16) is mounted in relation to the contact surface or the three contact points to enable centering in a hole.

7.

A device as claimed in claim 6, characterized in:

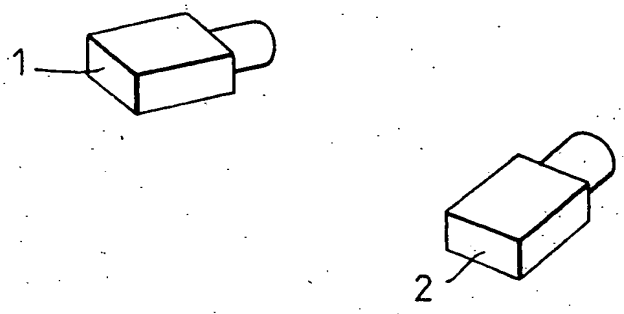
- that the guiding means (16) is conically shaped with a light source (14) attached thereto, such that one by determining the position of this light source is able to calculate the hole diameter, in addition to the center position and orientation of the hole.

8.

A device as claimed in claim 1, characterized in:

- that the contact surface of the probe is designed either as a cylinder (18) having a known diameter and a contact rim (19), or having one or more known contact edges (23) which enable positioning thereof in a hole parallel to the center axis of the hole and where these contact edges have known position and orientation relative to the light sources of the probe, such that by letting the contact surface touch the side of the hole at a minimum of three positions, and by a determining the positions of the light sources, the basis is being made up for a calculation of the position, diameter and orientation of the hole.

Fig. 1.



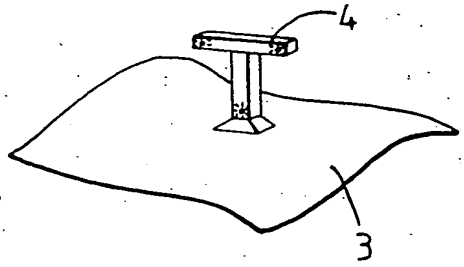


Fig. 2a.

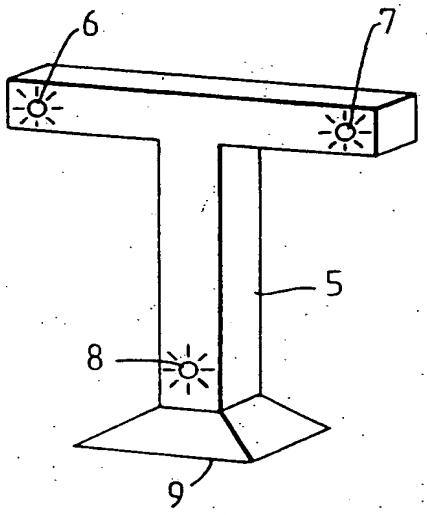


Fig. 2b.

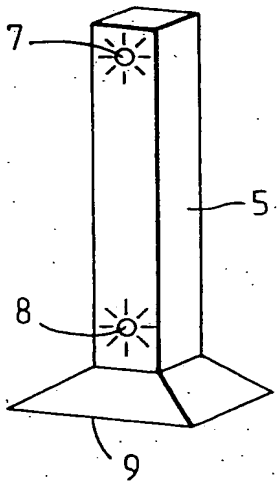


Fig. 3a.

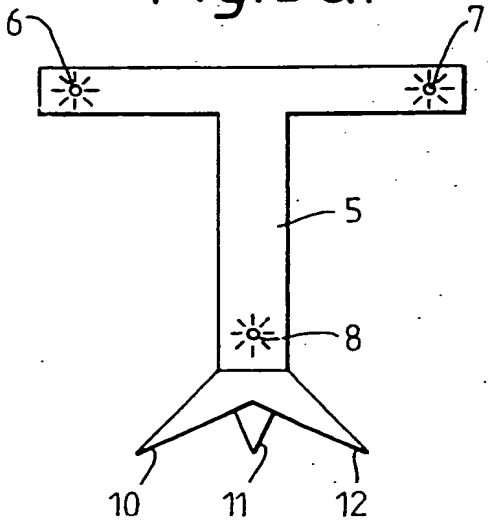


Fig. 3b.

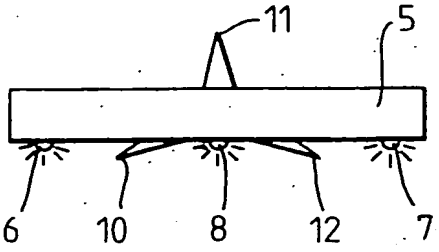


Fig. 4a.

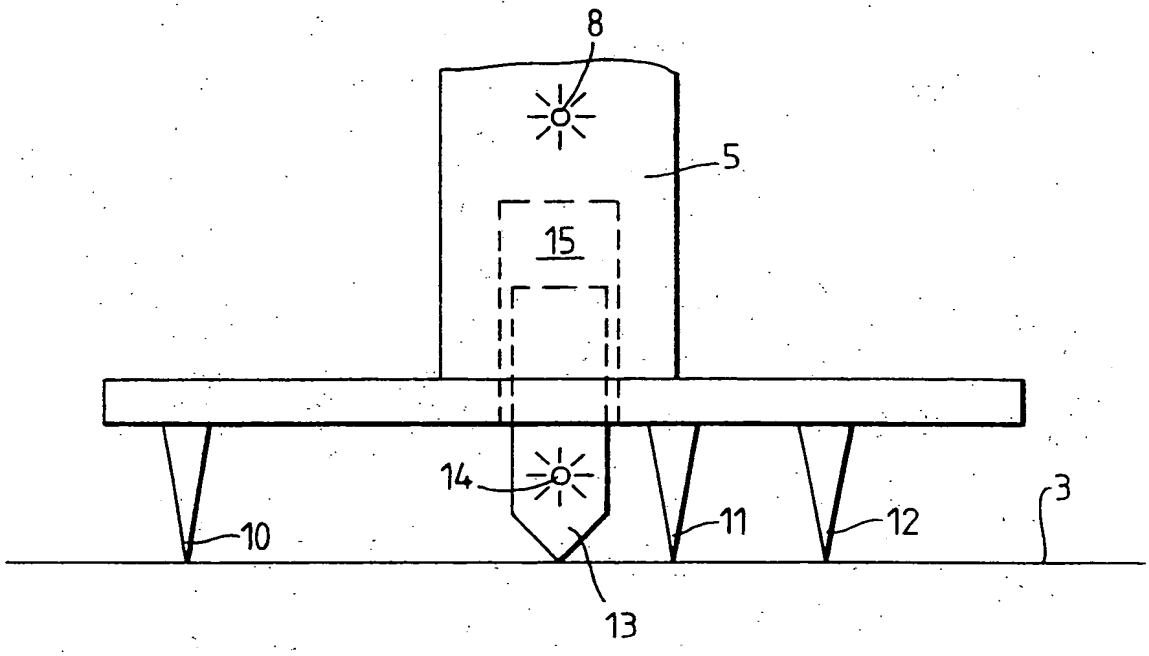


Fig. 4b.

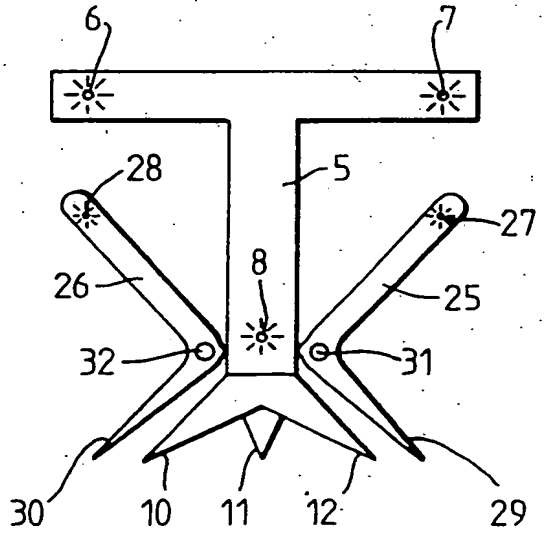


Fig. 5.

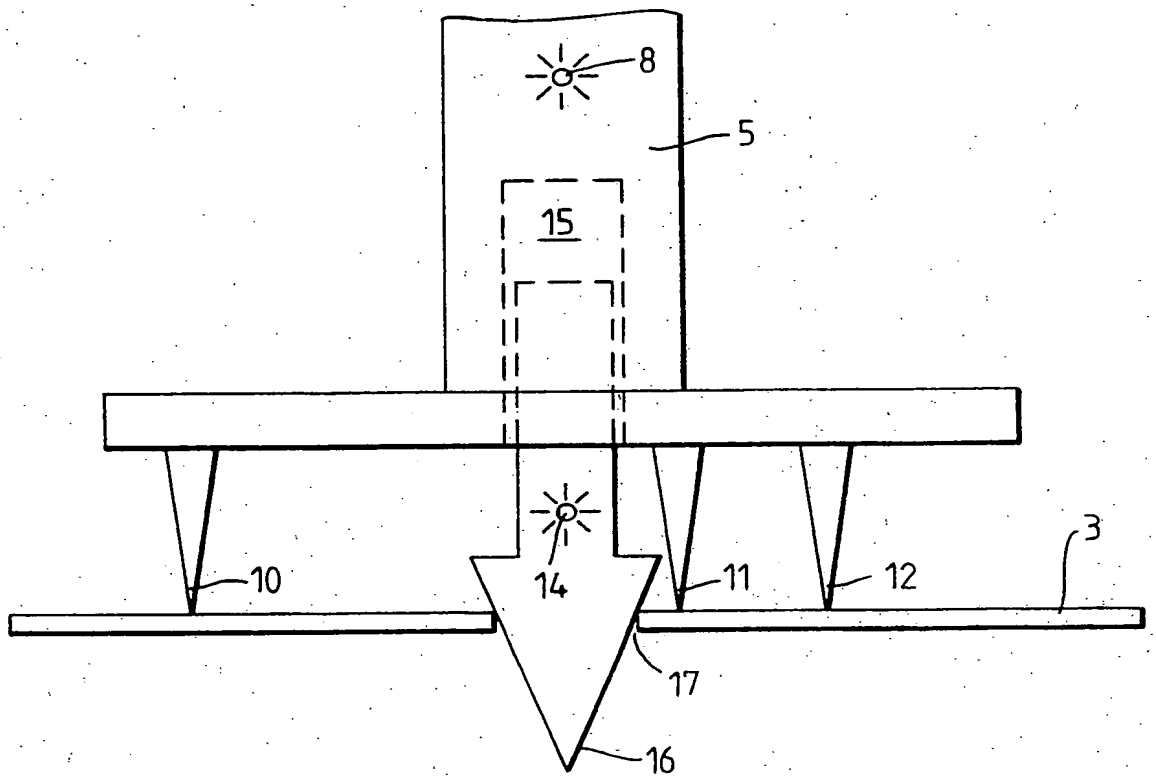


Fig. 6.

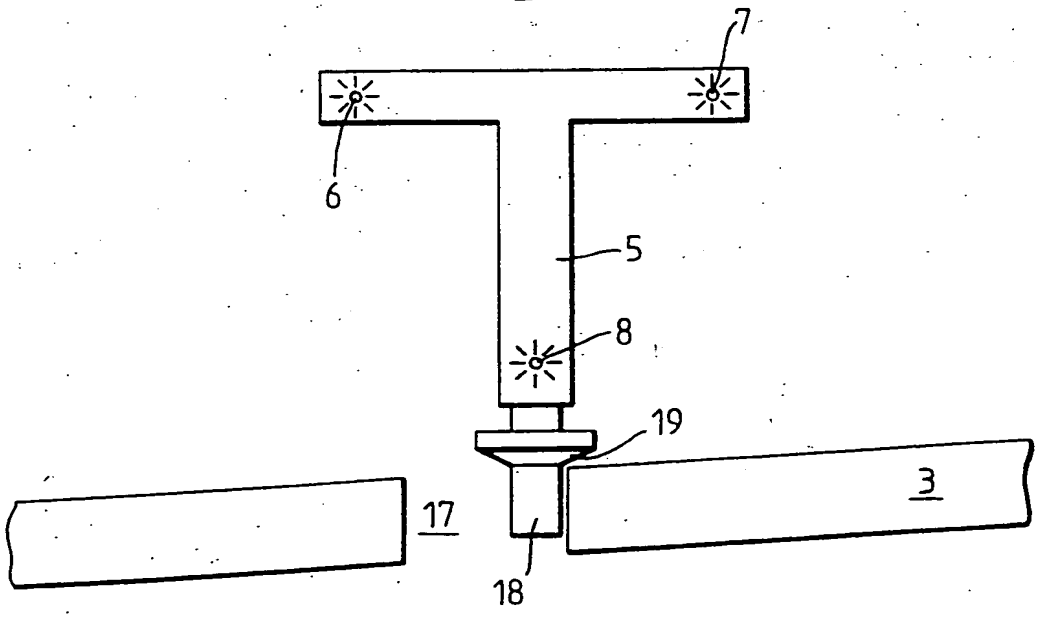


Fig. 7a.

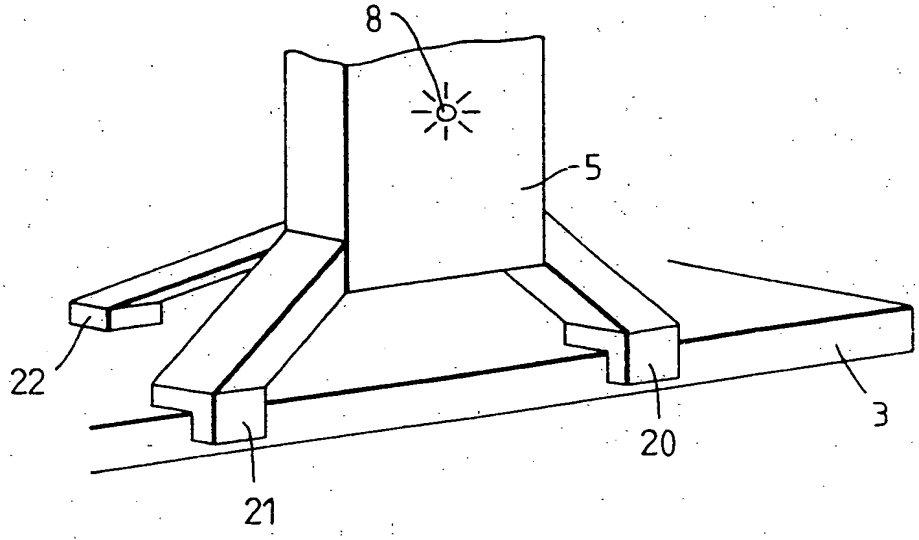


Fig. 7b.

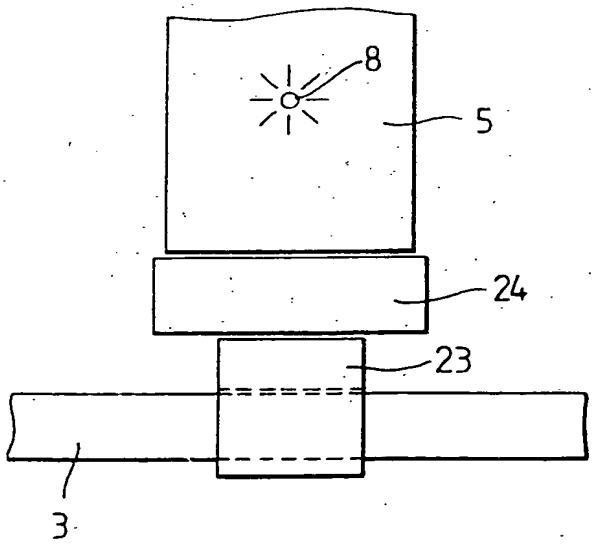
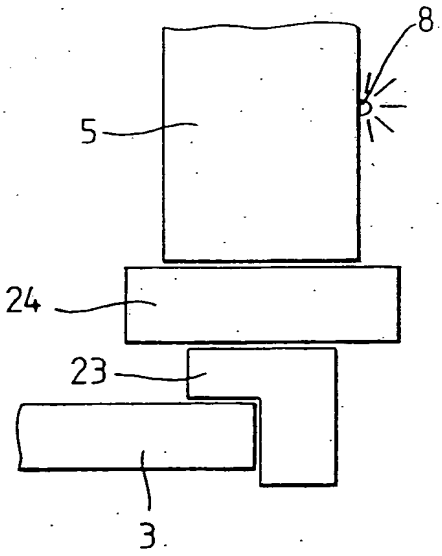


Fig. 7c.



INTERNATIONAL SEARCH REPORT

International Application No PCT/NO 91/00063

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: G 01 B 11/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	G 01 B; G 01 C

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
A	SE, B, 456454 (LARS DAVID HUGE LINDQVIST) 3 October 1988, SEE THE WHOLE DOCUMENT, CITED IN THE APPLICATION -- ---	1

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
22nd July 1991	1991 -07- 30
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	INGEMAR JOSEFSSON

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/NO 91/00063

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 91-06-27
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
SE-B- 456454	88-10-03	SE-A- 8700638	88-08-18